

Experimental summary of SUSY Dark Matter searches at the LHC

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Introduction

- In R-parity conserved SUSY models, the lightest supersymmetric particle (LSP) is a suitable candidate for Dark Matter.
 - Sparticles are produced in a pair, each decays to LSP, leading large E_T^{miss}.
 - Mixing of wino, bino and two neutral higgsinos gives four neutralinos.
 - In most models, the LSP is the lightest neutralino or gravitino.
- Search for LSP at the LHC
 - Direct LSP pair production is not accessible due to low cross-sections.
 - The LSP is typically produced at the end of cascade decays of heavier sparticles.

Constrains on the LSP mass depends on the considered mass spectrum.



Outline

- SUSY search strategy
- Selected SUSY DM results by ATLAS and CMS with the full 8 TeV dataset
 - Inclusive searches for squarks and gluinos
 - Third generation squarks
 - Electroweak production
- Conclusions

SUSY search strategy

• SUSY pair productions at the LHC:



 gluinos and 1st and 2nd gen. squarks with high cross-section, reachable up to > 1 TeV mass
3rd gen. squarks with moderate cross-section, up to ~0.5 TeV
^g gen. squarks with moderate cross-section, up to ~0.5 TeV
- charginos, neutralinos and sleptons with small crosssection, becoming feasible with the current dataset.

Sparticles decay into characteristic signatures:
e.g. E_T^{miss}, (*b*/*c*-) jets, leptons, and photons.

 \rightarrow Designed various analyses to cover many signatures^{*p*}.

EW SUSY

Squark and gluino search in all-hadronic events



• Agreement between data and SM background prediction.

Interpretation



arXiv:1405.7875
Results are interpreted in terms of squark and gluino pair production.



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Searches for stop pair production

 Large spectrum of possible stop decays is covered by several dedicated analyses with 0/1/2-leptons+(*b/c*-)jets.



In $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^{\circ}$, exclusion at massless LSP: m_{stop} <645 GeV. Up to m_{LSP} <230 GeV.

GMSB models: gravitino LSP



arXiv:1407.0603

- Signatures depend on the next-to-lightest sparticles (NLSP).
- Stau NLSP
- Signature: τ + jets + E_T^{miss}





Bino NLSP

ATLAS-CONF-2014-001

Signature: 2γ + jets + E_{T}^{miss} Gluino EW production ∑a 1600 5¹⁰⁰ Observed (± 1 σ_{T}^{SI} Observed (± 1 σ ATLAS Preliminary Expected (± 1 σ_{rm}) ATLAS Preliminary 900 ⁽⁾ Е production Expected (± 1 σ_{Evr} L dt = 20.3 fb⁻¹, **i**s = 8 TeV Expected (± 2 σ_{Exp}) 800 3 1400 Ε 70 1300 600 1200 (First reinterpretation) 500 1100 400 \boldsymbol{p} 1000 W/Z/h1200 1400 200 400 600 800 1000 300^t 500 800 m (χ̃₁0) [GeV] 200 600 700 300 400 m ($\tilde{\chi}_{1}^{0}$) [GeV] Experimental summary of SUSY Dark Matter searches at the LHC (Yu Nakahama) 8



GMSB models: Higgsino NLSP

- Higgsino NLSP in stop pair production
- Signature: Z + *b*-jets

700 L dt = 20.3 fb⁻¹, vs = 8 Te m_r [GeV]

Higgsino NLSP in gluino and EW productions Phys. Rev. D.

Stop production



Searches for chargino/neutralino production

- Clean signature: multi leptons, depending on slepton masses and gauge mixture.
- Many possible models are covered by several comprehensive analyses.



Interpretation of EW production in pMSSM



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- Phenomenological MSSM (pMSSM) can put generic constraints on most of the phenomenological features of the RPC MSSM.
- Interpretation of 2-lepton+3-lepton analyses in pMSSM:
 - on higgsino μ wino M_2 mass-plane also with very large slepton masses.
 - Assumption is bino mass $M_1 = 50$ GeV and tan $\beta = 10$.



Search for EW production with Higgs



CMS-SUS-14-002, arXiv:1409.3168

- Higgs discovery opens up new SUSY searches:
 - Lightest neutral *CP*-even Higgs (h) expected to be SM-like, if others heavy.
 - Neutralino can decay to h/Z+LSP.
- CMS performed comprehensive search program with diboson + E_T^{miss} including hh, Zh, Wh.

- h→ZZ, WW, γγ, bb





pMSSM interpretation of CMS results



- CMS reinterpreted 7 and 8 TeV searches in pMSSM.
- pMSSM points were selected to be compatible with LEP exclusions and flavor physics results, assuming neutralino LSP and sparticle masses < 3 TeV.
- Constrained by the CMS EW and inclusive $H_T + E_T^{miss}$ (+*b*-jets) searches.
 - Blue filled areas show the prior distributions before taking into account CMS analyses.
 Black lines show posterior distributions after including the CMS analyses.
 - Data slightly disfavor small neutralino masses.¹



Constraints on DM-related quantities



- If a series of SUSY signals is observed, features of cascade decays will help to determine DM-related quantities.
- Demonstrated the influences of the CMS SUSY searches on DM-related quantities:
 - CMS data slightly prefer lower densities.
 - lower p- $\tilde{\chi}_{_{1}}^{_{0}}$ scattering cross sections are marginally favored.

Conclusion

- ATLAS and CMS performed comprehensive programs of SUSY DM searches with the 8 TeV full dataset to cover as many signatures and models as possible.
 - e.g. Increased coverage for difficult SUSY regions. Performed new analyses with Higgs in the SUSY cascade decays.
 - Plenty of public results are available: ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- Run2 data at 13 TeV will explore wider phase spaces and further increase discovery potential of SUSY DM.
- Searches for DM in SUSY cascade decays are complementary to direct searches.

Backup slides

Summary of ATLAS SUSY results

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

ATLAS Preliminary $\sqrt{s} = 7.8$ TeV

0.0	Model	e, μ, τ, γ	Jets	E_{-}^{miss}	$\int \mathcal{L} dt [fb]$	b ⁻¹]	Mass limit		Reference
Inclusive Searches	$\begin{array}{c} MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ \tilde{q}\bar{q}, \bar{q} \rightarrow q \tilde{x}_{10}^0 \\ \tilde{g}\bar{s}, \bar{s} \rightarrow q \bar{q} \tilde{x}_{1}^0 \\ \tilde{g}\bar{s}, \bar{s} \rightarrow q \bar{q} \tilde{x}_{1}^0 \\ \tilde{g}\bar{s}, \bar{s} \rightarrow q \bar{q} \tilde{x}_{1}^0 \rightarrow q q W^{\pm} \tilde{x}_{1}^0 \\ \tilde{g}\bar{s}, \bar{s} \rightarrow q q \mathcal{C}[\ell/r/\nu) \tilde{x}_{1}^0 \\ GMSB (\tilde{\ell} \ NLSP) \\ GGM \ (bino \ NLSP) \\ GGM \ (bing \ sino-bino \ NLSP) \\ GGM \ (higgsino-bino \ NLSP) \\ GGM \ (higgsino \ NLSP) \\ GGM \ (higgsino \ NLSP) \\ Gravitino \ LSP \end{array}$	$\begin{array}{c} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 1 \ 2 \ r, h - 10 \ 1 \\ 2 \\ \gamma \\ 1 \ e, \mu + \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{array}$	2-6 jets 3-6 jets 7-10 jets 2-6 jets 2-6 jets 3-6 jets 3-6 jets 0-3 jets 0-2 jets 1 b 0-3 jets mono-jet	T Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	$\begin{array}{c} \bar{q}, \bar{g} \\ \bar{g}, \bar{g} \\ \bar{g}$	1.7 TeV 1.2 TeV 1.2 TeV 1.3 TeV 1.1 TeV 850 GeV 1.33 TeV 1.18 TeV 1.18 TeV 1.12 TeV 1.24 TeV 1.24 TeV 1.24 TeV 1.28 TeV 619 GeV 900 GeV 690 GeV 645 GeV	$\begin{array}{l} m(\bar{q}) \!=\! m(\bar{g}) \\ any m(\bar{q}) \\ any m(\bar{q}) \\ m(\bar{\chi}^0) \!=\! 0 \text{GeV}, m(1^{st} \text{gen}, \bar{q}) \!=\! m(2^{nd} \text{gen}, \bar{q}) \\ m(\bar{\chi}^0) \!=\! 0 \text{GeV} \\ m(\bar{\chi}^0) \!=\! 200 \text{GeV}, m(\bar{\chi}^z) \!=\! 0.5(m(\bar{\chi}^0) \!+\! m(\bar{g})) \\ m(\bar{\chi}^0) \!=\! 0 \text{GeV} \\ tan\beta \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \!$	1405.7875 ATLAS-CONF-2013-062 1308.1841 1405.7875 1405.7875 ATLAS-CONF-2013-062 ATLAS-CONF-2013-062 ATLAS-CONF-2013-063 ATLAS-CONF-2012-144 1211.1167 ATLAS-CONF-2012-152 ATLAS-CONF-2012-152
3 rd gen. Ĩ med.	$\begin{array}{l} \tilde{g} \rightarrow b \bar{b} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow b \bar{t} \tilde{\chi}_{1}^{1} \end{array}$	0 0 0-1 <i>e</i> , μ 0-1 <i>e</i> , μ	3 b 7-10 jets 3 b 3 b	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	55 55 55 55 55 55	1.25 TeV 1.1 TeV 1.34 TeV 1.34 TeV 1.3 TeV	$\begin{array}{l} {\mathfrak m}(\tilde{\lambda}_1^0){<}400{\rm GeV} \\ {\mathfrak m}(\tilde{\lambda}_1^0){<}350{\rm GeV} \\ {\mathfrak m}(\tilde{\lambda}_1^0){<}400{\rm GeV} \\ {\mathfrak m}(\tilde{\lambda}_1^0){<}300{\rm GeV} \end{array}$	1407.0600 1308.1841 1407.0600 1407.0600
3 rd gen. squarks direct production	$ \begin{split} & \tilde{k}_{1}^{1}b_{1}, \tilde{b}_{1} \rightarrow b\tilde{k}_{1}^{0} \\ & \tilde{b}_{1}b_{1}, \tilde{b}_{1} \rightarrow t\tilde{k}_{1}^{\pm} \\ & \tilde{h}_{1}b_{1}, \tilde{b}_{1} \rightarrow t\tilde{k}_{1}^{\pm} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{light}), \tilde{i}_{1} \rightarrow b\tilde{k}_{1}^{\pm} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{medium}), \tilde{i}_{1} \rightarrow b\tilde{k}_{1}^{\pm} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{medium}), \tilde{i}_{1} \rightarrow b\tilde{k}_{1}^{\pm} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{neavy}), \tilde{i}_{1} \rightarrow k_{0}^{0} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{neavy}), \tilde{i}_{1} \rightarrow k_{0}^{0} \\ & \tilde{i}_{1}\tilde{i}_{1}(\text{neav}), \tilde{i}_{1} \rightarrow k_{0}^{0} \\ & \tilde{i}_{1}\tilde{i}$	$\begin{matrix} 0 \\ 2 \ e, \mu \ (SS) \\ 1-2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 3 \ e, \mu \ (Z) \end{matrix}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b nono-jet/c-t 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.1 20.3 4.7 20.3 20.3 20.1 20 20.1 20.3 20.3 20.3 20.3	\tilde{b}_1 \tilde{b}_1 \tilde{t}_2	100-620 GeV 275-440 GeV 110-167 GeV 130-210 GeV 215-530 GeV 215-580 GeV 210-640 GeV 260-640 GeV 90-240 GeV 150-580 GeV 290-600 GeV	$\begin{split} & m(\tilde{k}_1^{i}) <& 90 \; GeV \\ & m(\tilde{k}_1^{i}) =& 2m(\tilde{k}_1^{i}) \\ & m(\tilde{k}_1^{i}) =& m(\tilde{k}_1^{i}) \\ & m(\tilde{k}_1^{i}) =& m(\tilde{k}_1^{i}) =& 16eV \\ & m(\tilde{k}_1^{i}) =& 16eV \\ & m(\tilde{k}_1^{i}) =& 26eV \\ & m(\tilde{k}_1^{i}) =& 256eV \\ & m(\tilde{k}_1^{i}) =& 250 \; GeV \\ & 250 \; GeV \\ &$	1308.2631 1404.2500 1208.4305, 1209.2102 1403.4853 1308.2631 1407.0583 1406.1122 1407.0608 1403.5222 1403.5222
EW direct	$ \begin{array}{c} \tilde{\ell}_{\perp R} \tilde{\ell}_{\perp R}, \tilde{\ell} \rightarrow \ell \tilde{k}_{1}^{0} \\ \tilde{k}_{1}^{*} \tilde{k}_{1}^{*}, \tilde{k}_{1}^{*} \rightarrow \ell \nu (\tilde{v}) \\ \tilde{k}_{1}^{*} \tilde{k}_{1}^{*}, \tilde{k}_{1}^{*} \rightarrow \ell \nu (\tilde{v}) \\ \tilde{k}_{1}^{*} \tilde{k}_{2}^{*} \rightarrow \tilde{\ell}_{1} \nu \ell_{1}^{\ell} \ell (\tilde{v}) \\ \tilde{k}_{1}^{*} \tilde{k}_{2}^{*} \rightarrow \tilde{\ell}_{1} \nu \ell_{1}^{\ell} \ell (\tilde{v}) \\ \tilde{k}_{1}^{*} \tilde{k}_{2}^{*} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{*} \\ \tilde{k}_{2}^{*} \tilde{k}_{2}^{*} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{*} \\ \tilde{k}_{2}^{*} \tilde{k}_{2}^{*} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{*} \\ \tilde{k}_{2}^{*} \tilde{k}_{2}^{*} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{*} \end{array} $	2 e, µ 2 e, µ 2 τ 3 e, µ 2-3 e, µ 1 e, µ 4 e, µ	0 0 - 0 2 <i>b</i> 0	Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	$ \vec{l} \\ \vec{\tilde{\chi}}_{1}^{\pm} \\ \vec{\tilde{\chi}}_{1}^{\pm} \\ \vec{\tilde{\chi}}_{1}^{\pm} \\ \vec{\tilde{\chi}}_{1}^{\pm} \\ \vec{\tilde{\chi}}_{2}^{\pm} \\ \vec{\tilde{\chi}}_{1}^{\pm} \\ \vec{\tilde{\chi}}_{2}^{\pm} \\ $	90-325 GeV 140-465 GeV 100-350 GeV 700 GeV 420 GeV 285 GeV 620 GeV m(ξ ⁰)+	$\begin{split} m(\tilde{x}_{1}^{0}) &= 0 \text{ GeV } \\ m(\tilde{x}_{1}^{0}) &= 0 \text{ GeV }, m(\tilde{z}, \tilde{z}) &= 0.5(m(\tilde{x}_{1}^{0}) + m(\tilde{x}_{1}^{0})) \\ m(\tilde{x}_{1}^{0}) &= 0 \text{ GeV }, m(\tilde{\tau}, \tilde{z}) &= 0.5(m(\tilde{x}_{1}^{0}) + m(\tilde{x}_{1}^{0})) \\ m(\tilde{x}_{1}^{0}) &= m(\tilde{x}_{2}^{0}) = 0.5(m(\tilde{x}_{1}^{0}) + m(\tilde{x}_{1}^{0})) \\ m(\tilde{x}_{1}^{0}) &= m(\tilde{x}_{2}^{0}) = 0.5(ptons decoupled \\ m(\tilde{x}_{1}^{0}), m(\tilde{x}_{1}^{0}) &= 0.5(m(\tilde{x}_{2}^{0}) + m(\tilde{x}_{1}^{0})) \\ m(\tilde{x}_{1}^{0}) &= m(\tilde{x}, \tilde{z}) = 0.5(m(\tilde{x}_{2}^{0}) + m(\tilde{x}_{1}^{0})) \end{split}$	1403.5294 1403.5294 1407.0350 1402.7029 1403.5294, 1402.7029 ATLAS-CONF-2013-093 1405.5086
Long-lived particles	Direct $\tilde{\chi}_{1}^{\dagger}\tilde{\chi}_{1}^{-}$ prod., long-lived $\tilde{\chi}_{1}^{\pm}$ Stable, stopped \tilde{g} R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_{1}^{0} \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, GMSB, \tilde{\chi}_{1}^{0} \rightarrow \gamma \tilde{G}, \text{ long-lived } \tilde{\chi}_{1}^{0}$ $\tilde{q}\tilde{q}, \tilde{\chi}_{1}^{0} \rightarrow qq\mu$ (RPV)	Disapp. trk 0 μ) 1-2 μ 2 γ 1 μ, displ. vtx	1 jet 1-5 jets - - -	Yes Yes Yes	20.3 27.9 15.9 4.7 20.3	$ \begin{array}{c} \tilde{\chi}_1^{\pm} \\ \tilde{g} \\ \tilde{\chi}_1^{0} \\ \tilde{\chi}_1^{0} \\ \tilde{q} \end{array} $	270 GeV 832 GeV 475 GeV 230 GeV 1.0 TeV	$\begin{array}{l} m(\tilde{\chi}_1^+) - m(\tilde{\chi}_1^0) = 160 \ \text{MeV}, \tau(\tilde{\chi}_1^+) = 0.2 \ \text{ns} \\ m(\tilde{\chi}_1^0) = 100 \ \text{GeV}, 10 \ \mu \text{s} < \tau(\tilde{g}) < 1000 \ \text{s} \\ 10 < \tan \! \beta < 50 \\ 0.4 < \tau(\tilde{\chi}_1^0) < 2 \ \text{ns} \\ 1.5 < cr < 156 \ \text{nm}, \text{BR}(\mu) = 1, \ m(\tilde{\chi}_1^0) = 108 \ \text{GeV} \end{array}$	ATLAS-CONF-2013-069 1310.6584 ATLAS-CONF-2013-058 1304.6310 ATLAS-CONF-2013-092
RPV	$\begin{array}{l} LFV \ pp \rightarrow \tilde{v}_\tau + X, \tilde{v}_\tau \rightarrow e + \mu \\ LFV \ pp \rightarrow \tilde{v}_\tau + X, \tilde{v}_\tau \rightarrow e(\mu) + \tau \\ Biinear \ RPV \ CMSSM \\ \tilde{\lambda}_1^+ \tilde{\lambda}_1^-, \tilde{\lambda}_1^+ \rightarrow W \tilde{\lambda}_1^0, \tilde{\lambda}_1^0 \rightarrow e \tilde{v}_\mu, e \mu \tilde{v}_e \\ \tilde{\lambda}_1^+ \tilde{\lambda}_1^-, \tilde{\lambda}_1^+ \rightarrow W \tilde{\lambda}_1^0, \tilde{\lambda}_1^0 \rightarrow \tau \tau \tilde{v}_e, e \tau \tilde{v}_\tau \\ \tilde{g} \rightarrow q q \\ \tilde{g} \rightarrow \tilde{q} q \\ \tilde{g} \rightarrow \tilde{q} \tau_1 \tilde{t}, \tilde{t}_1 \rightarrow b s \end{array}$	$\begin{array}{c} 2 e, \mu \\ 1 e, \mu + \tau \\ 2 e, \mu (\text{SS}) \\ 4 e, \mu \\ 3 e, \mu + \tau \\ 0 \\ 2 e, \mu (\text{SS}) \end{array}$	- 0-3 b - - 6-7 jets 0-3 b	- Yes Yes Yes - Yes	4.6 4.6 20.3 20.3 20.3 20.3 20.3 20.3	$ \begin{array}{c} \tilde{v}_{\tau} \\ \tilde{v}_{\tau} \\ \tilde{q}_{, \sharp} \\ \tilde{\chi}_{1}^{, \sharp} \\ \tilde{\chi}_{1}^{, \sharp} \\ \tilde{g} \\ \tilde{g} \\ \tilde{g} \end{array} $	1.61 TeV 1.1 TeV 1.35 TeV 750 GeV 450 GeV 916 GeV 850 GeV	$\begin{array}{l} \lambda_{311}^{*}=0.10,\lambda_{132}=0.05\\ \lambda_{311}^{*}=0.10,\lambda_{1(233)}=0.05\\ \mathfrak{m}(\vec{a})=\mathfrak{m}(\vec{a}),c_{12,5}=c-1\ \mathrm{mm}\\ \mathfrak{m}(\vec{c}_{1}^{*})=0.2\times \mathfrak{m}(\vec{c}_{1}^{*}),\lambda_{121}\neq 0\\ \mathfrak{m}(\vec{c}_{1}^{*})>0.2\times \mathfrak{m}(\vec{c}_{1}^{*}),\lambda_{133}\neq 0\\ BR(r)=BR(r)=BR(r)=BR(r)=0\% \end{array}$	1212.1272 1212.1272 1404.2500 1405.5086 1405.5086 ATLAS-CONF-2013-091 1404.250
Other	Scalar gluon pair, sgluon $\rightarrow q\bar{q}$ Scalar gluon pair, sgluon $\rightarrow t\bar{t}$ WIMP interaction (D5, Dirac χ)	$\frac{0}{2 e, \mu (SS)}$	4 jets 2 <i>b</i> mono-jet	- Yes Yes	4.6 14.3 10.5	sgluon sgluon M* scale	100-287 GeV 350-800 GeV 704 GeV	incl. limit from 1110.2693 $\mathrm{m}_{(\chi)}{<}\mathrm{80~GeV}, \mathrm{limit~of}{<}\mathrm{687~GeV} \text{ for D8}$	1210.4826 ATLAS-CONF-2013-051 ATLAS-CONF-2012-147
	full data P	artial data	full	data			10 ' 1	Mass scale [TeV]	

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 σ theoretical signal cross section uncertainty.

Summary of CMS SUSY results



SUSY analysis strategy

- Set kinematic signal regions to enhance signals w.r.t. SM backgrounds.
 - Discriminating variables: e.g. E_T^{miss} , N_{jets} , effective mass $m_{eff} = E_T^{miss} + H_T$ (scalar sum of jet, lepton p_T)
- Determine background contributions.
 - SM backgrounds: top, multijets, W, Z, VV, Higgs, ...
 - Reducible backgrounds: determined from data, depending on analyses.
 - Irreducible backgrounds: normalize MC in data control regions where each background process is dominant.
- Check background predication using validation region data close to signal regions.
- Look for SUSY excess in data signal regions and interpret the observed results.

Search for direct stop production by CMS



Search for EW production by CMS



pMSSM interpretation of CMS results



CMS-SUSY-13-020

Flat pMSSM parameters:	Non-CMS data used				
19-dementional priors	i	Observable	Constraint	Likelihood function	
		$\mu_j(\theta)$	D _j non-DCS	$L(D_j^{\text{non-DCS}} \mu_j(\theta))$	
$-3 \text{ ToV} \leq M$, $M_2 \leq 3 \text{ ToV}$	1a	$BR(b \rightarrow s\gamma)$ [43, 44]	$(3.55 \pm 0.23^{\text{stat}} \pm 0.24^{\text{th}} \pm 0.09^{\text{sys}}) \times 10^{-4}$	Gaussian	
$-5 \text{ Iev} \leq 101_1, 101_2 \leq 5 \text{ Iev}$	1b	$BR(b \rightarrow s\gamma)$ [45]	$(3.43 \pm 0.21^{\text{start}} \pm 0.24^{\text{trt}} \pm 0.07^{\text{sys}}) \times 10^{-4}$	Gaussian	
$0 < M_{\rm e} < 3 \mathrm{TeV}$	2a	$BR(B_s \rightarrow \mu\mu)$ [46]	observed CLs curve from [46]	$d(1 - CLs)/d(BR(B_s \rightarrow \mu\mu))$	
$0 \leq 1/13 \leq 5$ lev	2b	$BR(B_s \rightarrow \mu\mu)$ [47]	$(2.9 \pm 0.7 \pm 0.29^{**}) \times 10^{-9}$	Gaussian	
$-3 \text{ ToV} \leq 1 \leq 3 \text{ ToV}$	3a	$R(B_{\rm N} \rightarrow \tau \nu)[36, 48]$	1.63 ± 0.54	Gaussian	
$-5 \text{ Iev} \leq \mu \leq 5 \text{ Iev}$	3b	$R(B_u \rightarrow \tau \nu)[45]$	1.04 ± 0.34	Gaussian	
$0 \leq m \leq 3 \text{ ToV}$	4	Δa_{μ} [49]	$(26.1 \pm 6.3^{exp} \pm 4.9^{ext} \pm 10.0^{eCST}) \times 10^{-10}$	Gaussian	
$0 \leq m_A \leq 5$ lev	5a	m_t [50]	$173.3 \pm 0.5^{\text{star}} \pm 1.3^{\text{sys}} \text{ GeV}$	Gaussian	
$2 \leq \tan \beta \leq 60$	5b	m _t [51]	$173.20 \pm 0.87^{\text{stat}} \pm 1.3^{\text{sys}} \text{ GeV}$	Gaussian	
$2 \leq tall p \leq 00$	6	$m_b(m_b)$ [48]	4.19 ^{+0.18} _{-0.06} GeV	Two-sided Gaussian	
$0 < \tilde{O} = \tilde{U} = \tilde{D} = \tilde{U} = \tilde{U} = \tilde{O} = \tilde{U} = \tilde{D} = \tilde{U} = \tilde{U}$	7	$\alpha_{\rm s}(M_Z)$ [48]	0.1184 ± 0.0007	Gaussian	
$0 \leq Q_{1,2}, u_{1,2}, D_{1,2}, L_{1,2}, E_{1,2}, Q_3, u_3, D_3, L_3, E_3 \leq 5$ Iev	8a	m_h	pre-LHC: $m_h^{ow} = 112$	1 if $m_h \ge m_h^{low}$	
7 TeV < A, $A < 7 TeV$				0 if $m_h < m_h^{low}$	
$= 7 \text{ Iev} \leq A_t, A_b, A_\tau \leq 7 \text{ Iev},$	8b	m _h	LHC: $m_h^{low} = 120, m_h^{up} = 130$	1 if $m_h^{low} \le m_h \le m_h^{u_p}$	
				0 if $m_h < m_h^{low}$ or $m_h > m_h^{up}$	
	9	sparticle	LEP [52]	1 if allowed	
		masses	(via micrOMEGAs [37-39])	0 if excluded	

Non CMS data upod

pMSSM points were selected to be compatible with LEP exclusions and flavor physics results.

CMS data used

Analysis	\sqrt{s}	L
Hadronic HT + MHT search	7 TeV	4.98 fb^{-1}
Hadronic HT + MET + b -jets search	7 TeV	$4.98 \ {\rm fb^{-1}}$
Leptonic search for EW prod. of $\widetilde{\chi}^0$, $\widetilde{\chi}^{\pm}$, \tilde{l}	7 TeV	$4.98 \ {\rm fb^{-1}}$
Hadronic HT + MHT search	8 TeV	$19.5 {\rm fb}^{-1}$
Hadronic HT + MET + b -jets search	8 TeV	19.4 fb^{-1}
Leptonic search for EW prod. of $\widetilde{\chi}^0$, $\widetilde{\chi}^{\pm}$, \tilde{l}	8 TeV	$19.5 {\rm fb}^{-1}$
(ss, 3l, and 4l channels)		